# eRD16: Forward/Backward Tracking at EIC using MAPS Detectors

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## Abstract

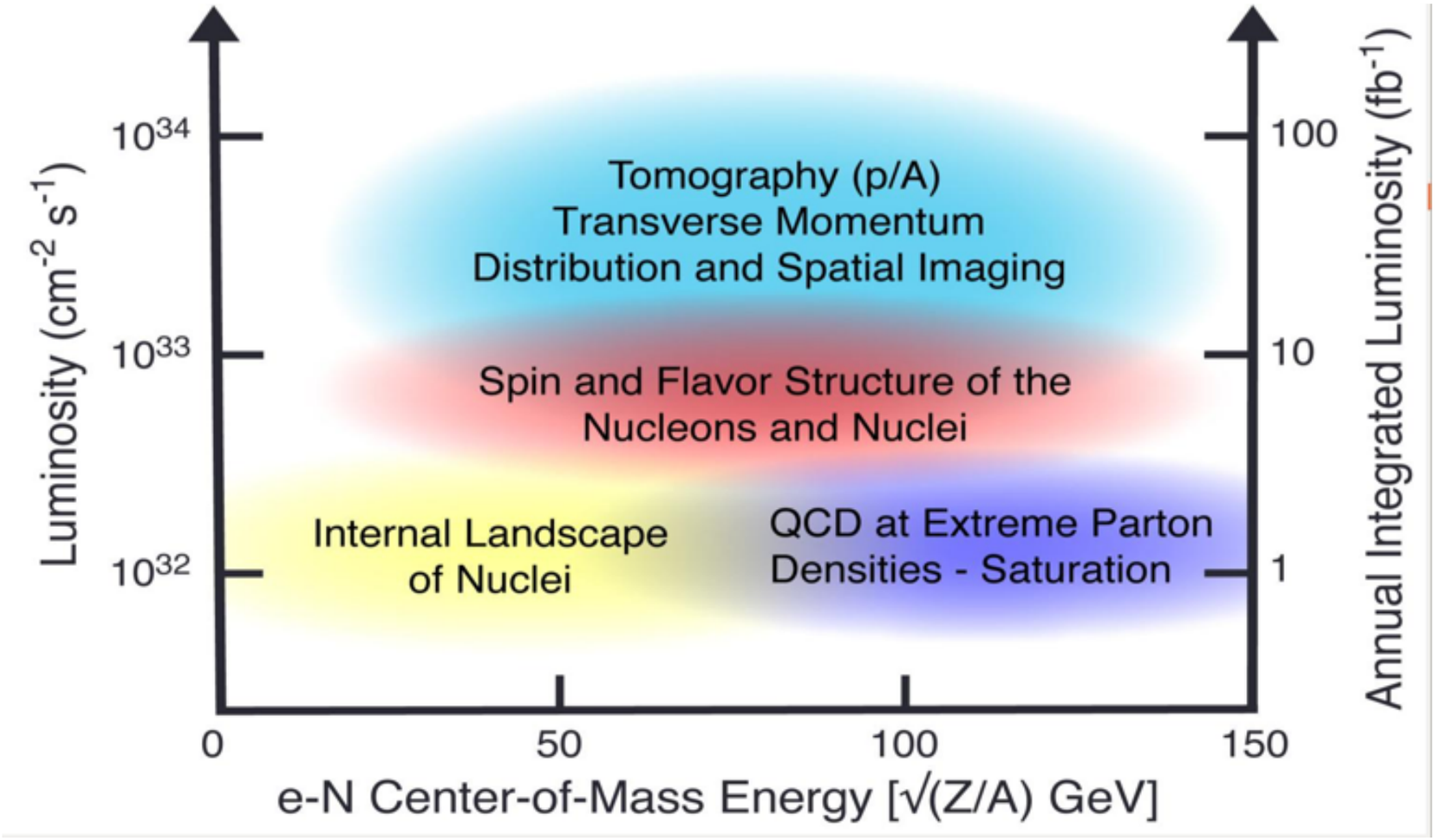
This report describes progress in the period between July and December 2018 on continued conceptual development of tracking stations with silicon-sensors near the collision vertex to detect the scattered electron and produced secondary hadrons at forward and backward angles with respect to the beams at a future Electron-Ion Collider. The focus is on disks with thinned-silicon sensors with the overall goal to arrive at science-driven sensor specifications, optimized geometrical configuration of the forward/backward disks, disk layout, conceptual arrangement of services, and integration with tracking subsystems covering the central barrel region. Part of this work is being pursued in collaboration with eRD18, which focuses on sensor development and mid-rapidity (vertex) tracking.

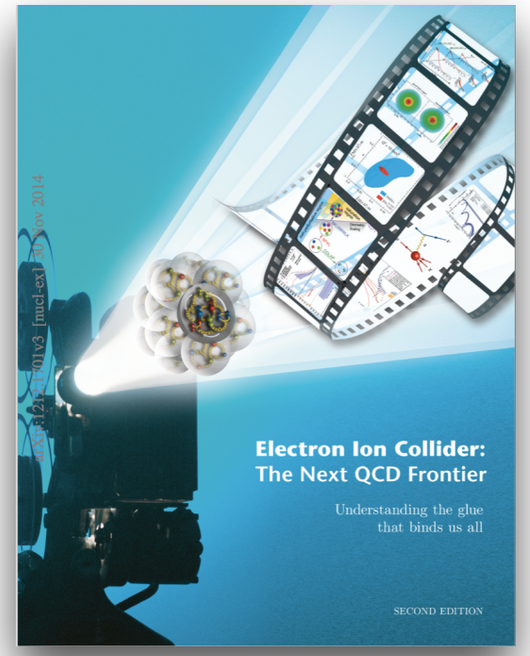
# Outline

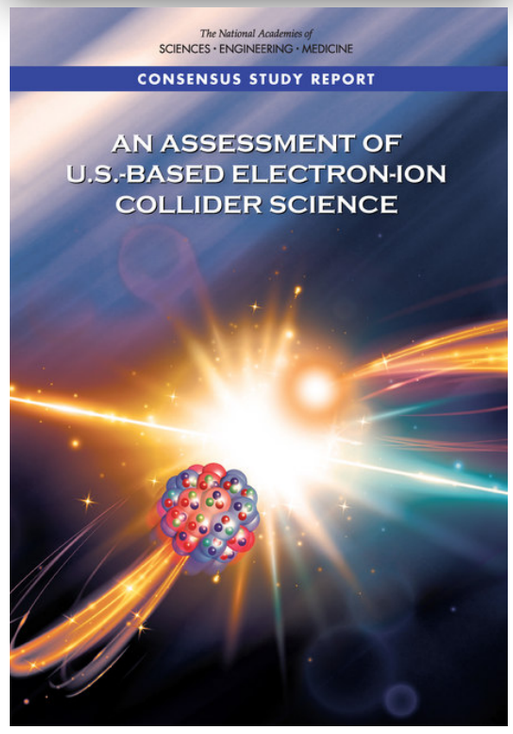
- Introduction / reminder
- Simulation tools used,
- Simulation progress on
  EICroot; comparison with LDT
  Revisit aspects of timing (-layer),
  Integration of disk and barrel tracker,
- Closing comments

# RNC - EIC Science Interests

Interest in *gluon-dense matter:*




implies a need for *high*-√s,
observables $F_2(x,Q^2)$, $F_L(x,Q^2)$, $g_1(x,Q^2)$ at *low*-x
+ diffraction, dijets, heavy flavor, …

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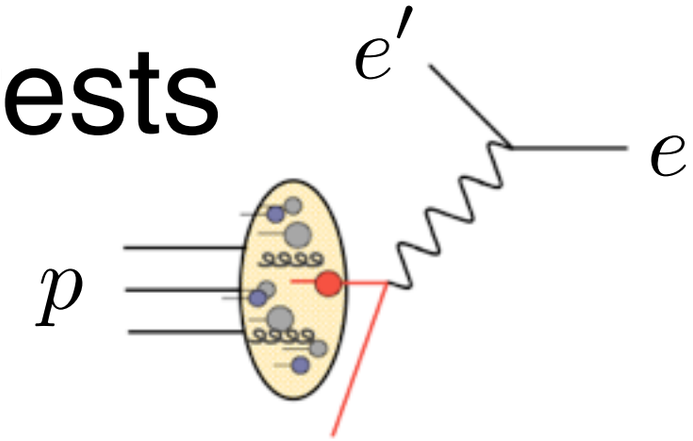


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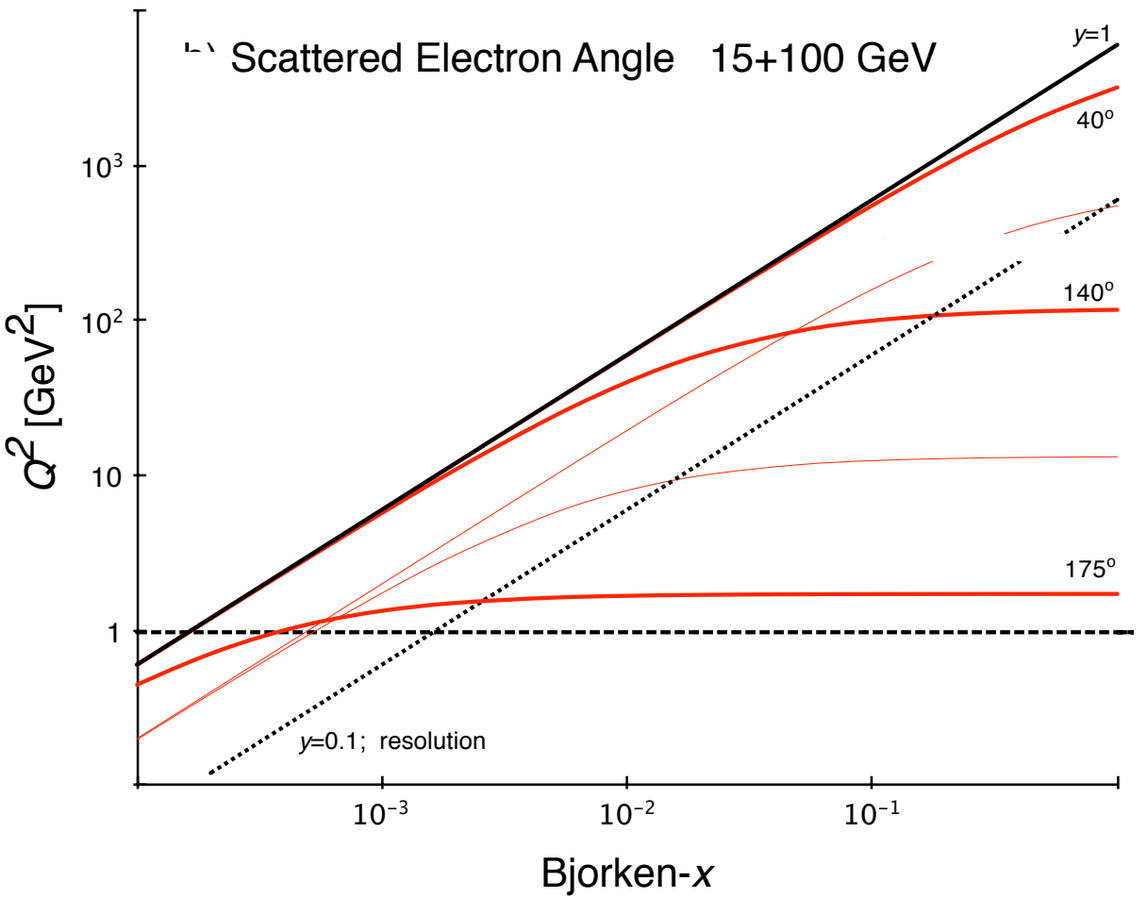
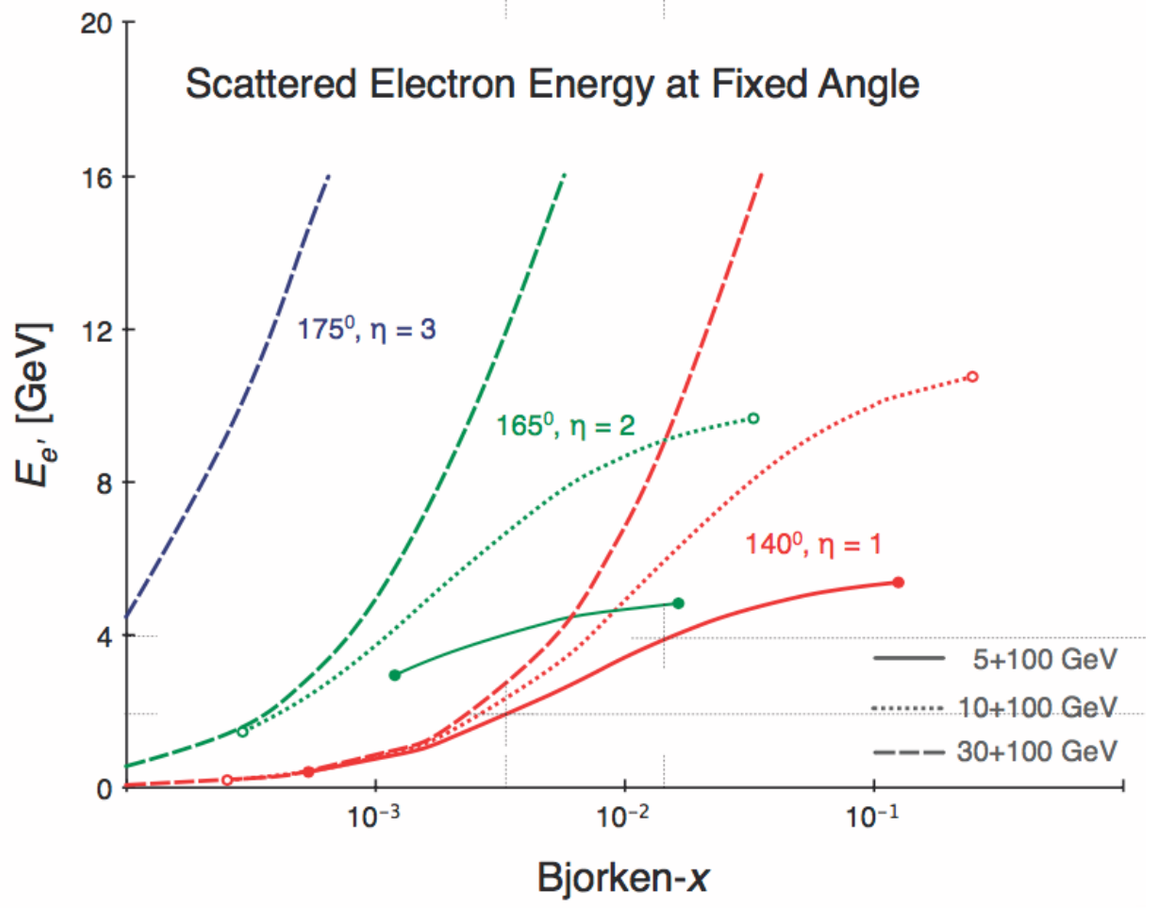


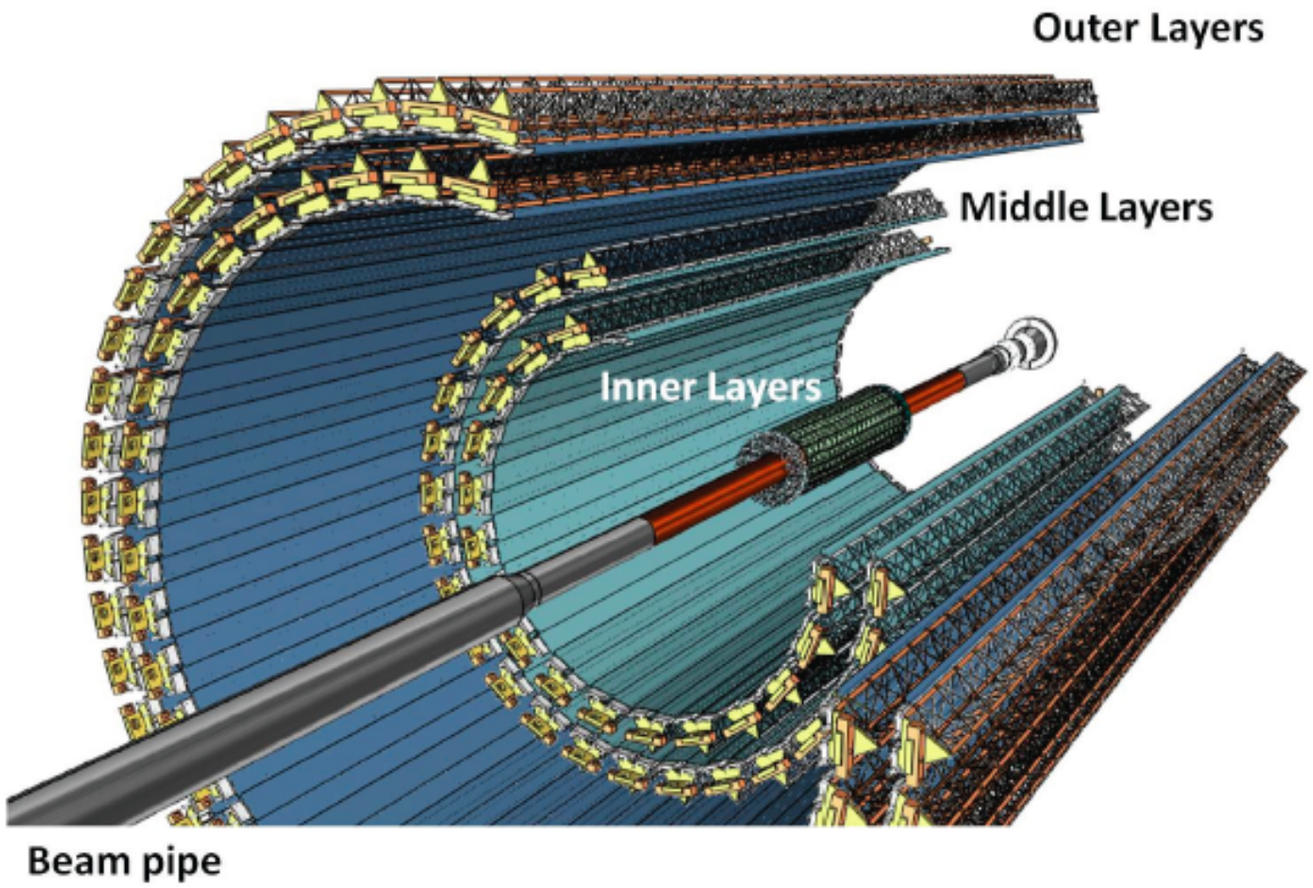

*necessitates* instrumentation at *backward* angles w.r.t. the hadron beam (HERA convention),

semi-inclusive observables do so at *forward* angles.

# RNC - Recent Instrumentation Projects

STAR HFT-pixel is complete,

ALICE ITS upgrade is ongoing,




- 7 layers
- 10 m^2 of silicon
- Installation in early 2019
- $X/X_0$ ~ 0.3% (inner layers)
- $X/X_0$ ~ 0.8% (outer layers)

Makes use of CERN-developed MAPS sensors, ALPIDE:

| | |
|---|---|
| Dimensions: | 15mm x 30mm |
| Pixel pitch: | 28µm x 28µm |
| Integration time: | approx. 4 µs |
| Power consumption: | 39mW/cm$^2$ |

TDR: http://iopscience.iop.org/0954-3899/41/8/087002/

Vertex tracker for sPHENIX being pursued.

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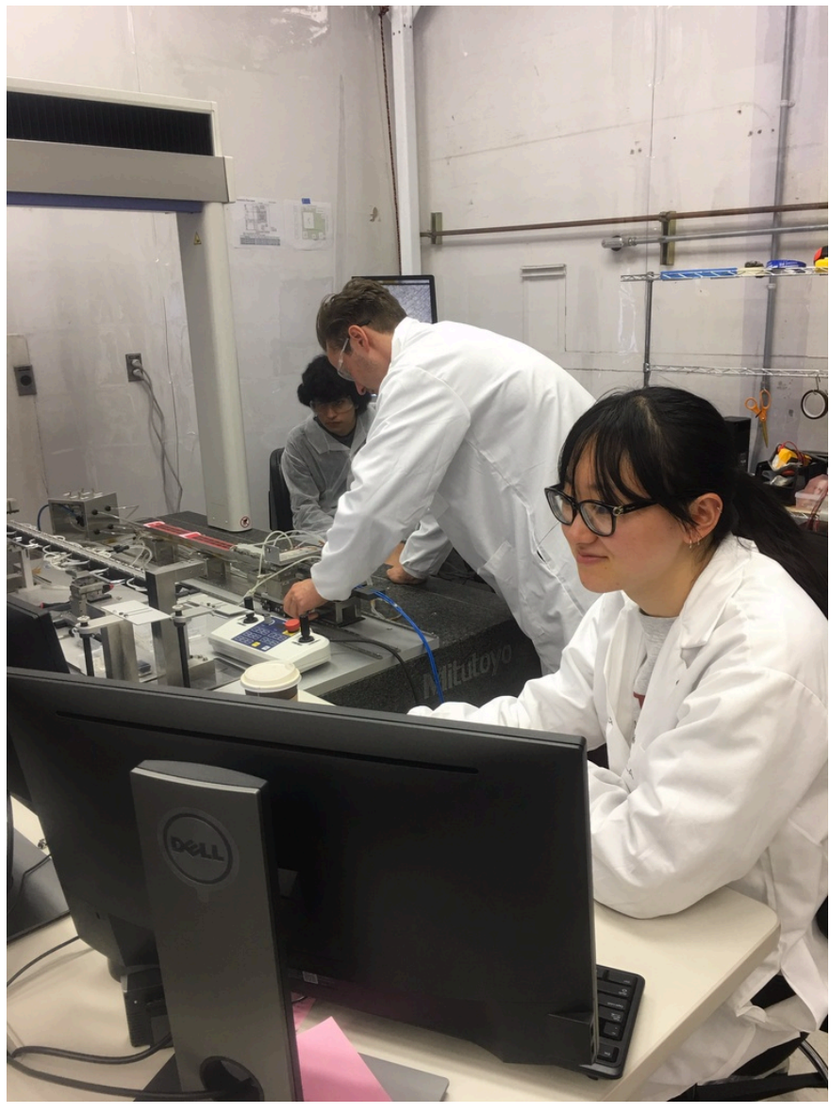

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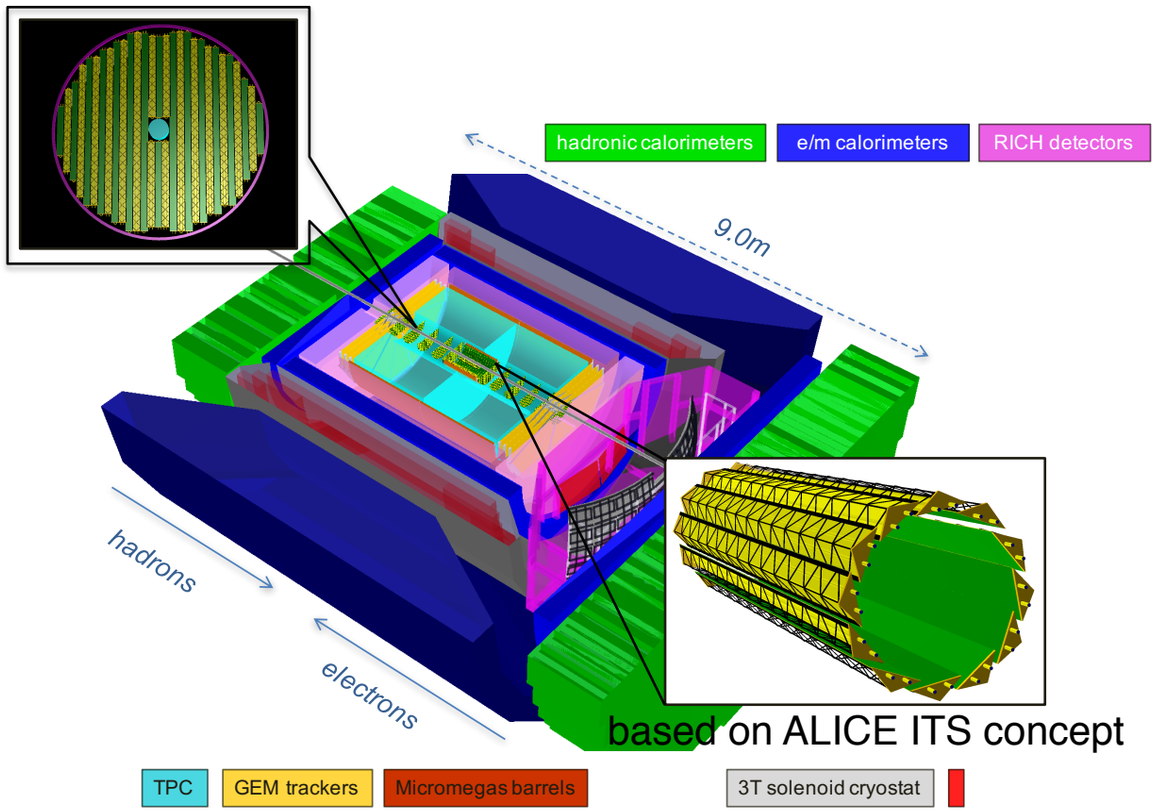
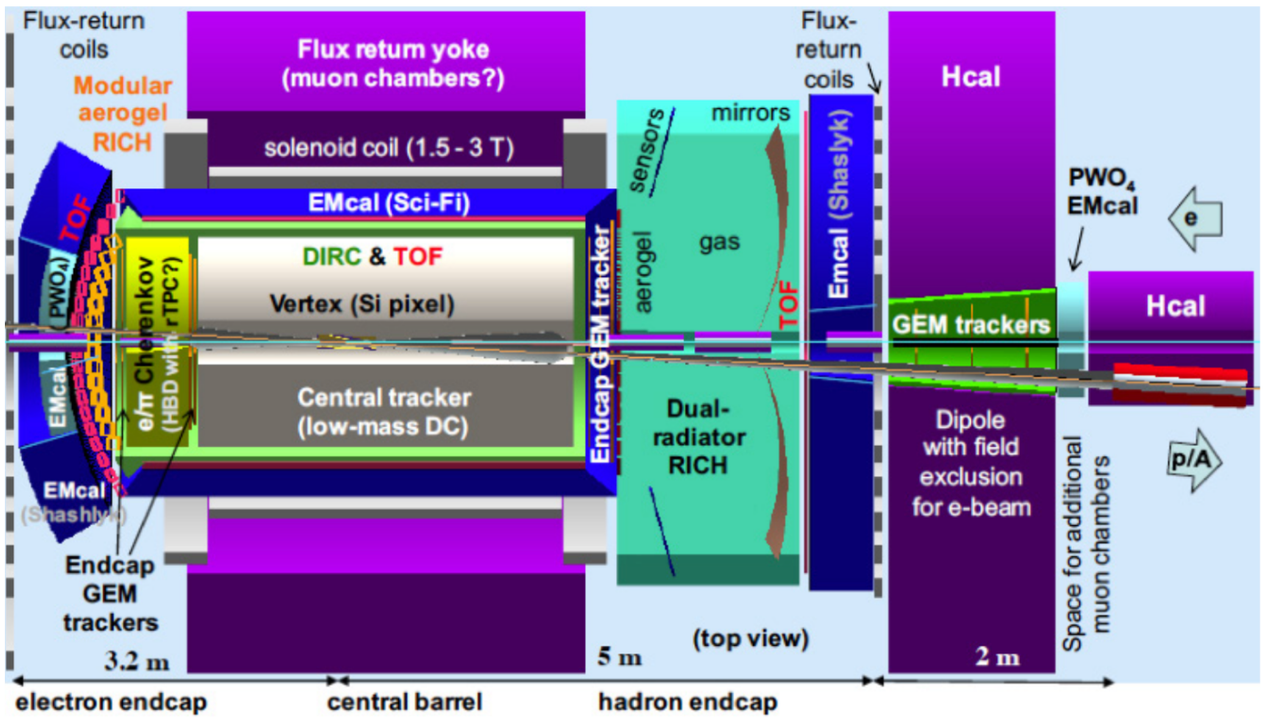
# EIC Detector Concepts*




BeAST concept




JLEIC detector concept

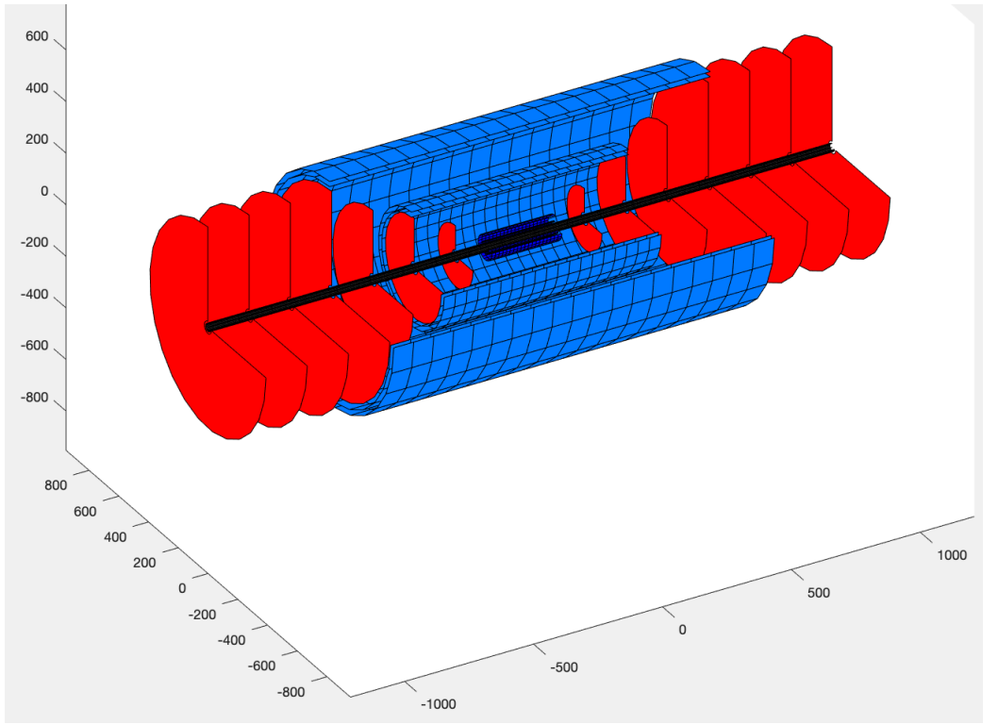
Si-based *inner* tracking and vertex detectors*, covering central and forward regions, for eRHIC as well as JLEIC detector concepts,

EIC needs: large acceptance, low mass, and high resolution.

*Other concepts exist; e.g. J. Repond et al. have put forward an all-Si tracker sPHENIX transition to a day-1 EIC detector.
All-Si detector concepts have thus far been mostly outside the scope of our R&D.

# eRD16 - EIC R&D Simulations

- Charged-particle tracking toolset originally developed for ILC studies by the Vienna group, M. Regler, M. Valentan, and R. Frühwirth (2008):
  - Helix track model,
  - Multiple scattering,
  - Full track reconstruction from digitized hits using a Kalman filter.




Hypothetical all-Si tracker in a 3T Solenoidal field.

- Rapid studies of number of layers, disks, geometrical layout, etc.
- Work done with SBU undergraduate student Emily Biermann, previously with UCB undergraduate students Ivan Velkovsky and Winston DeGraw.

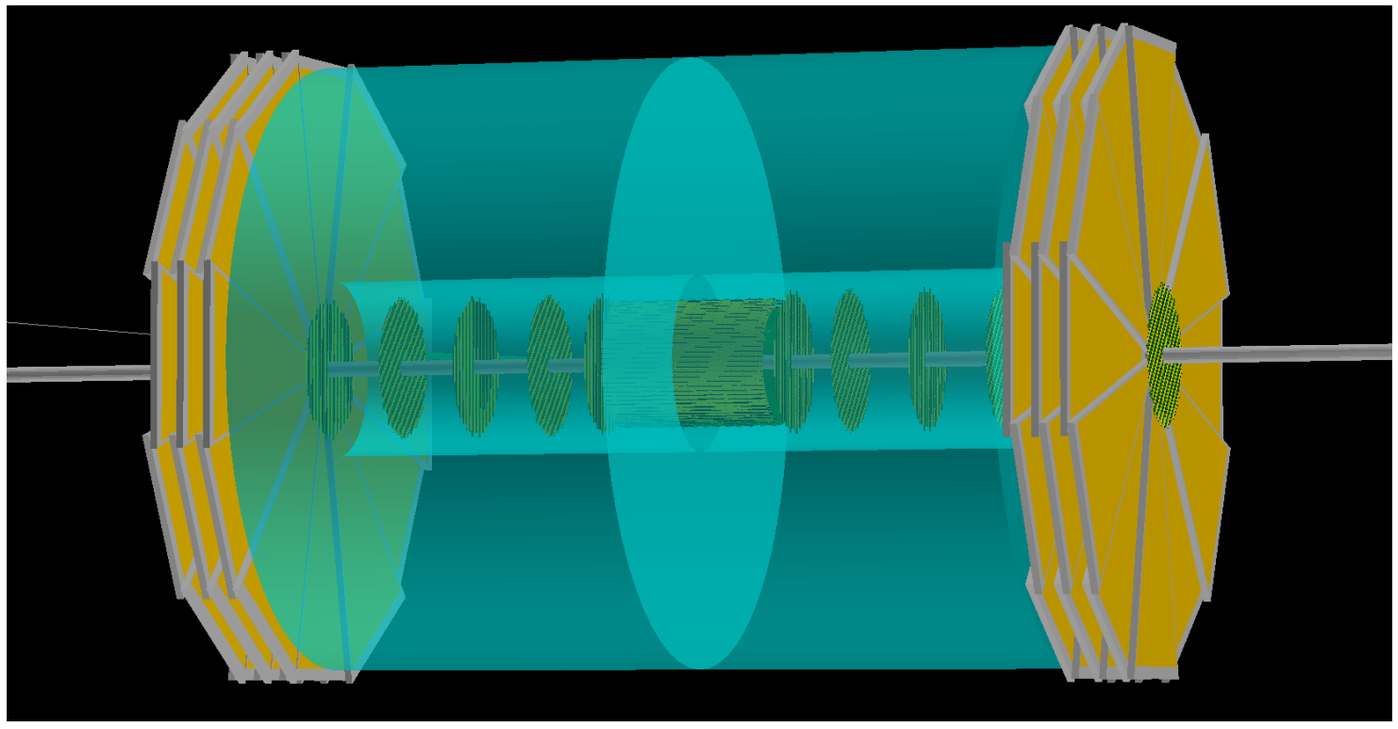
# eRD16 - EIC R&D Simulations

- Toolset(s) developed by EIC task-force at BNL;

  EICRoot; GEANT-based simulations

  Pythia-eRHIC,

  (EIC-smear)



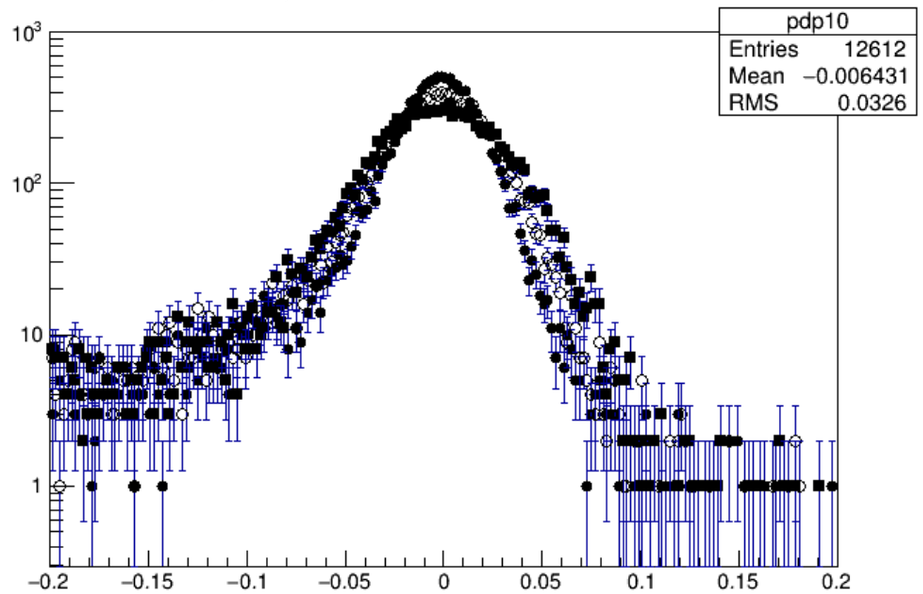
BeAST; seen are the TPC, Si-barrel and disks, and large-area GEMs

- Ongoing work by Yue Shi Lai, with the aim to
  confirm/refute key findings from fast simulations,
  changes to improve geometry and infrastructure,
  currently also E.S. and, past Summer, Ezra Lesser (UCB).
- Preferred toolset going forward, as the issues need more realistic answers, including e.g. integration with eRD18 barrel tracker,
- Going forward, anticipate to follow / adopt eRD20 work more closely

# eRD16 - EIC R&D Simulations

- For example,

10, 20, and 30 GeV electrons

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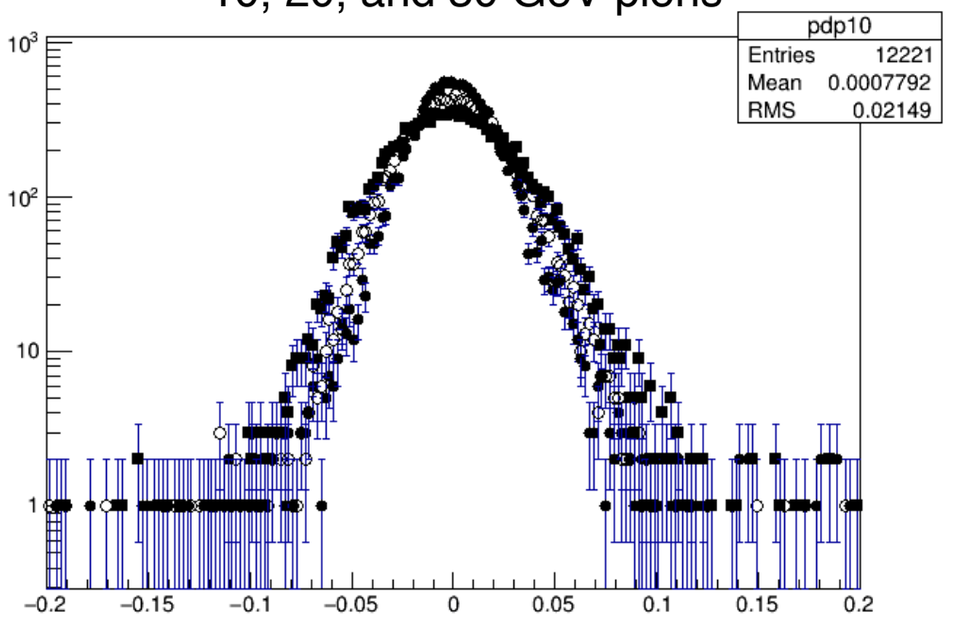
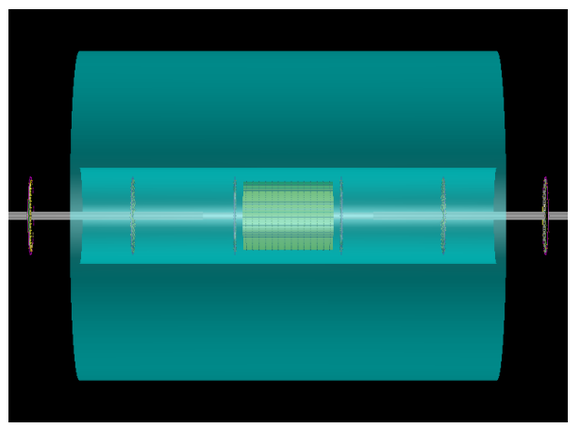


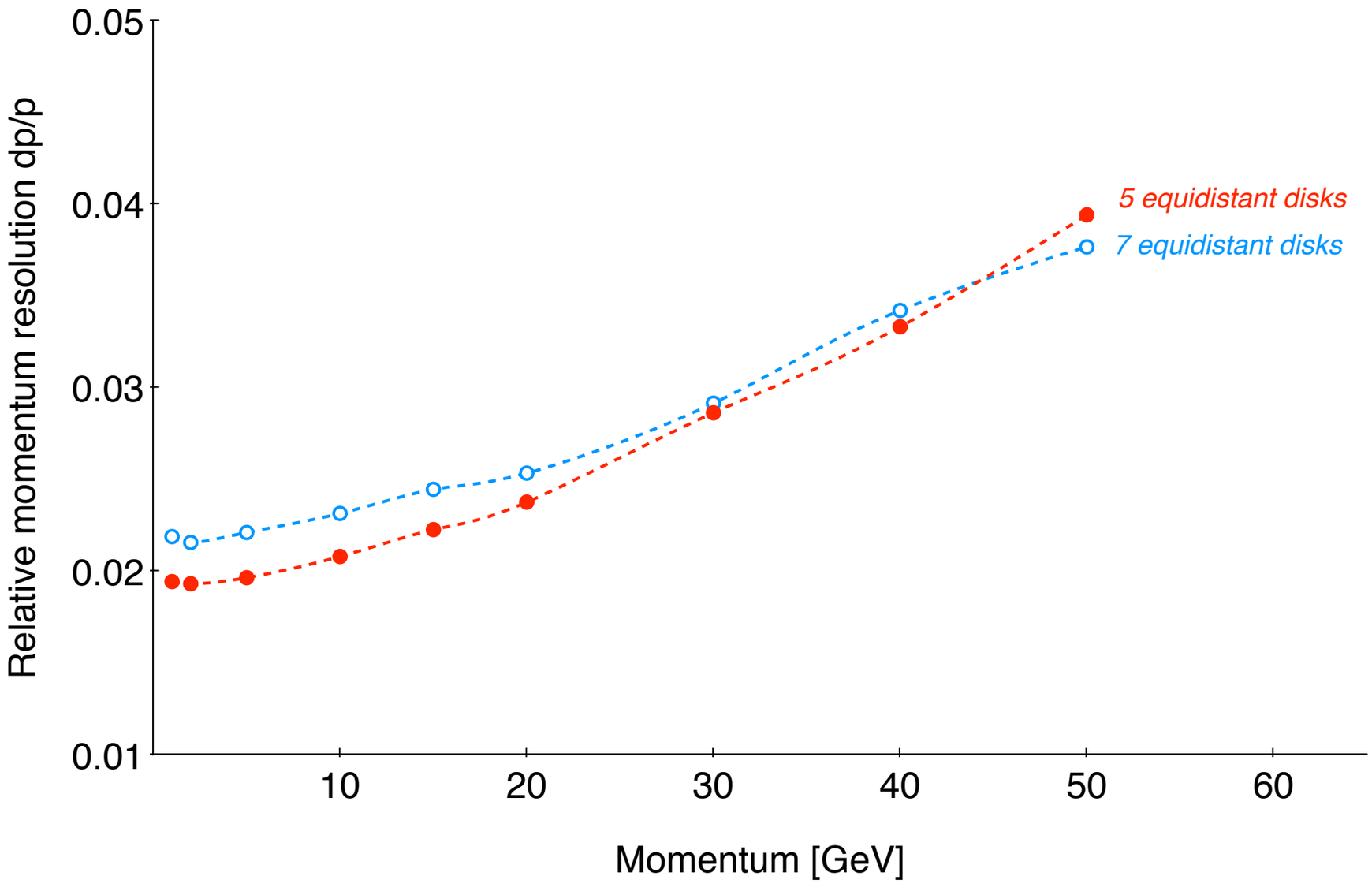

Tails (can/do) matter, even in a 3-disk simulation.



Tails handled in what follows by focusing on the central 2-3 sigma,

# eRD16 - EIC R&D Simulations

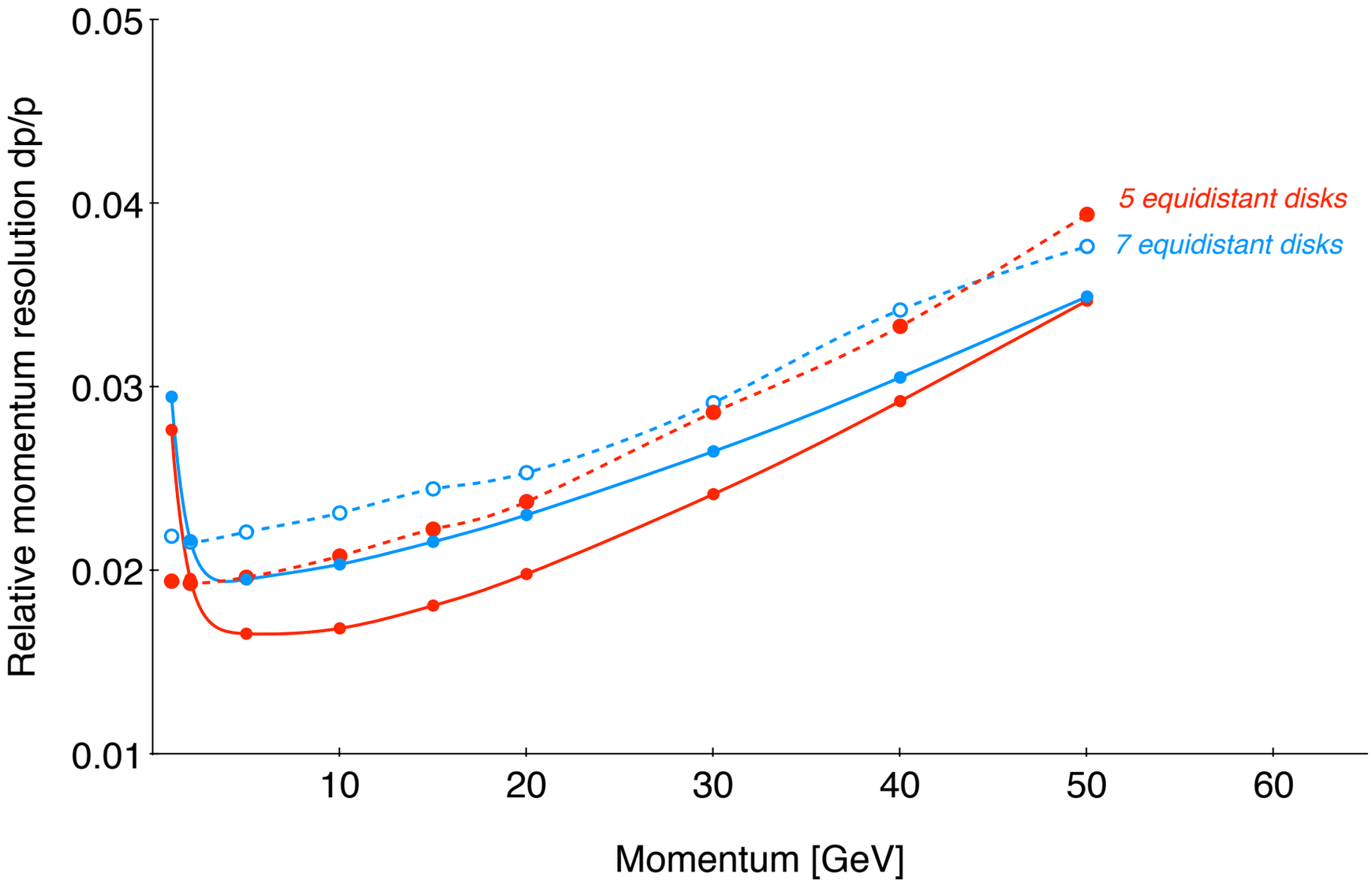
- E.g. disk-scan from EICroot,




Equidistant disks with 20μm² pixels, 3T field, 0.25 < z < 1.21m

# eRD16 - EIC R&D Simulations

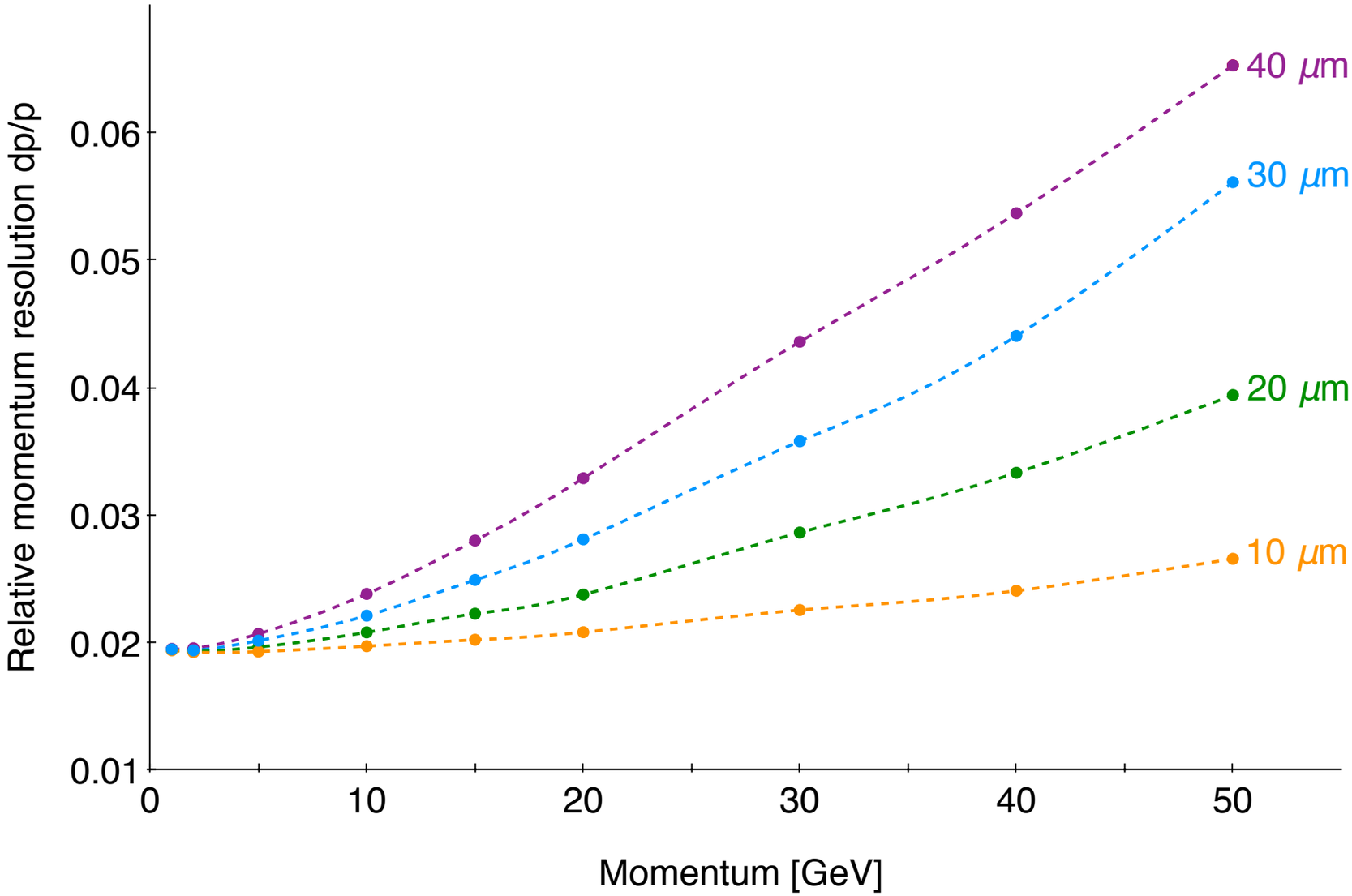
- E.g. disk-scan from EICroot compared to LDT fast-simulations,




Continuous curves from LDT fast-simulations - c.f. June 2017 writeup, corrected for 20$\mu$m$^2$ pixel size (28$\mu$m$^2$ in writeup).

# eRD16 - EIC R&D Simulations

- E.g. scan of pixel-size,



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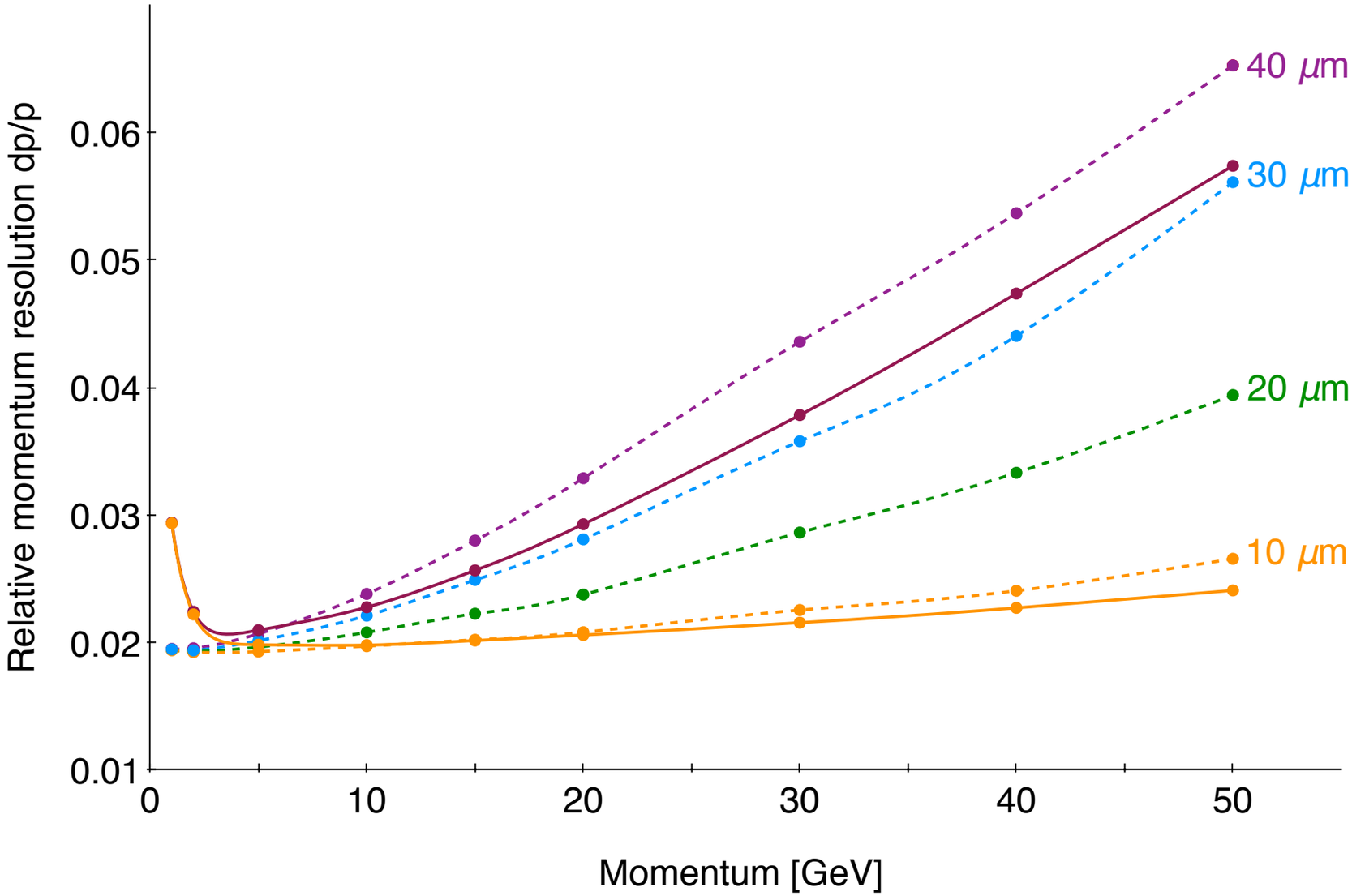



Continuous curves from LDT fast-simulations - c.f. July 2018 presentation.

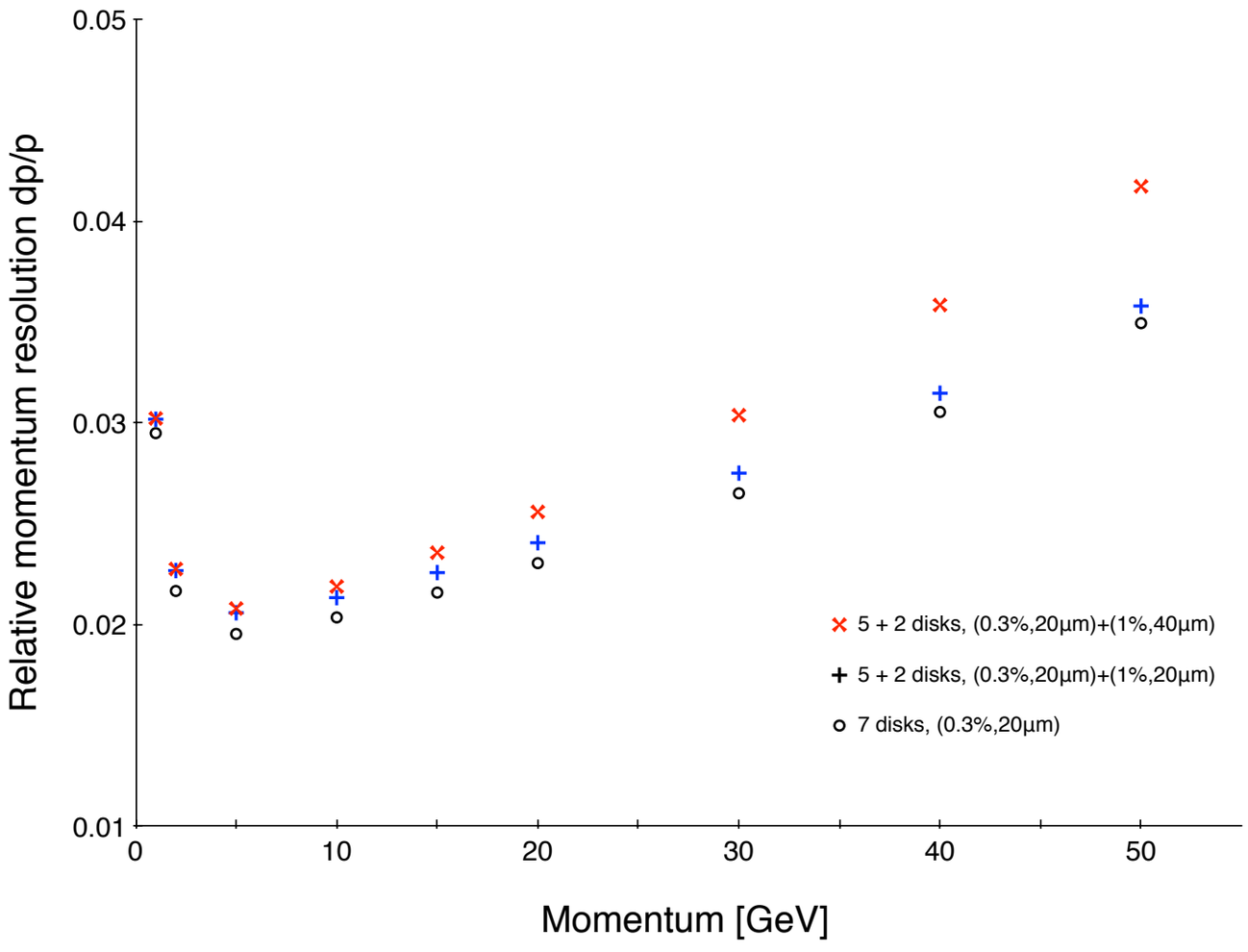
# eRD16 - EIC R&D Simulations

- Reasonable, or at least quantified, overall agreement between EICroot results and prior fast-simulations,
- Qualitative difference at small absolute momenta, in the region where absolute momentum (as opposed to $p_T$) is affected via the dip-angle by multiple scattering through the beam-pipe (slides in backup) - *being studied further,*
- EICroot simulations are now starting to catch up on fast simulations (where practical),
- Work starting on geometries (as opposed to configuration) and (conceptual) infrastructure,
- Anticipate to soon move to “Docker" (and otherwise start to follow more closely the work in eRD20).

# eRD16 - EIC R&D Simulations

- Outer instrumentation, possibly in the form of one or or more fast Si-disks or barrel layers, has come up previously in several discussions - eRD6, eRD16/18, … - as a timing-layer to anchor tracks to the crossing, suppress pile-up - previously studied by us and estimated to be manageable/small at EIC - and possibly even for ToF PID in parts of the acceptance (c.f. detector handbook),

- We studied "what-if" such a timing layer were to take the form of the two disks furthest from the interaction-point, and were to be somewhat thicker/coarser:



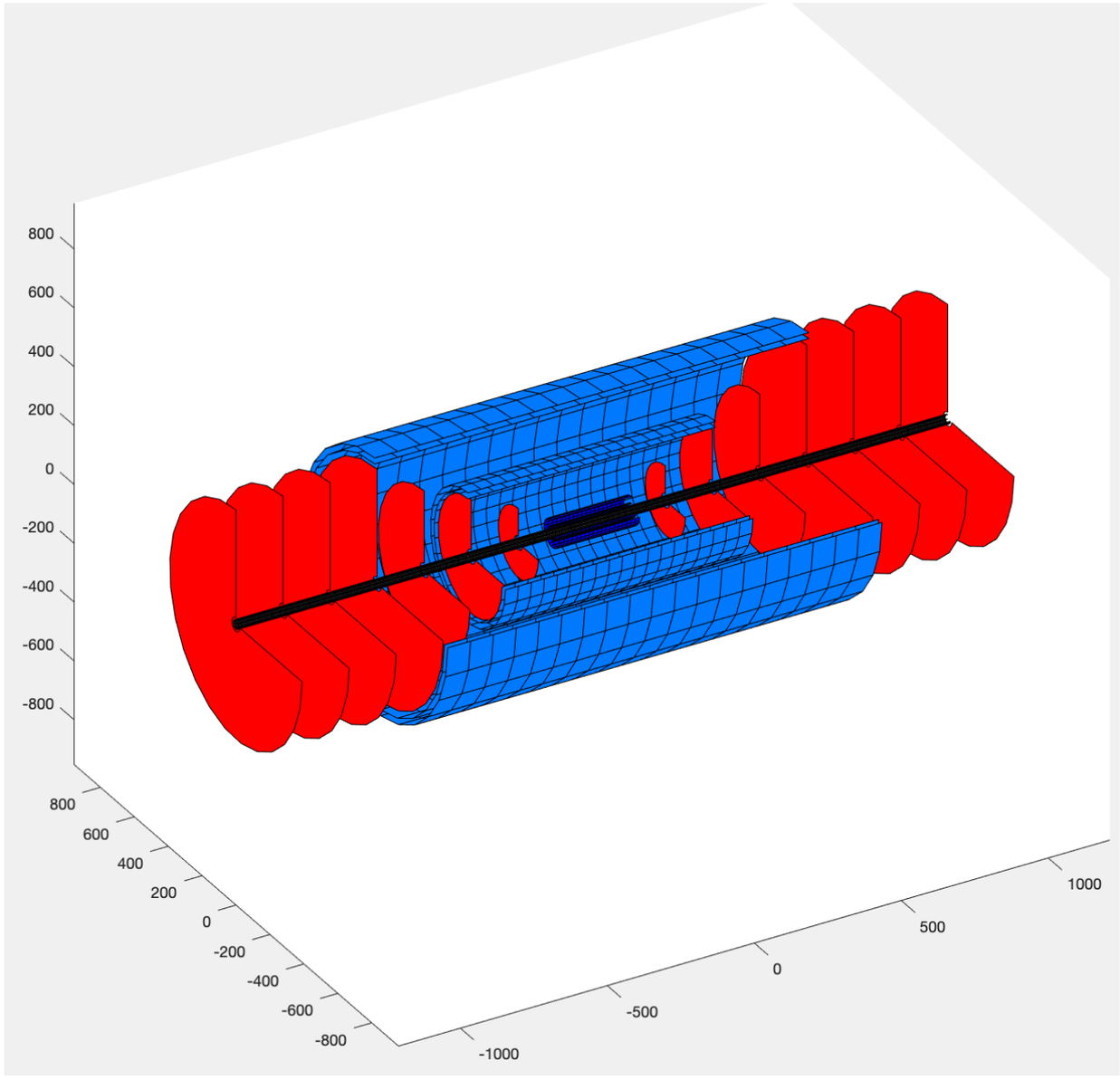

- added material will cause ~negligible degradation of dp/p,

- larger pixels at high-z are undesirable, especially for large momenta in the forward hadron region; avoidable e.g. by *adding* a timing-layer to the pixel-disks.

- Gaining group-interest (Y. Mei); *may* become a future instrumentation direction.

# eRD16 - EIC R&D Simulations

- Work started towards integration with a central tracker




A few key values,

- 270mm long outer vertex layer, at 46mm radius, covers down to ~19.1$^{o}$ or eta ~1.8
- 270mm long inner vertex layer, at 23mm radius, covers down to ~9.6$^{o}$ or eta ~2.5
- disk closest to IP at z = 250mm with 23mm inner radius, corresponding to ~5.3$^{o}$ or eta ~3.1
- outer barrel edges ~25-30$^{o}$ or eta between 1.35 and 1.5.

- An all-silicon tracker, two eRD18 vertex layers, seven eRD16 “tapered” equidistant disks in a BeAST configuration, and an ALICE-like outer barrel, in a 3T solenoidal field.

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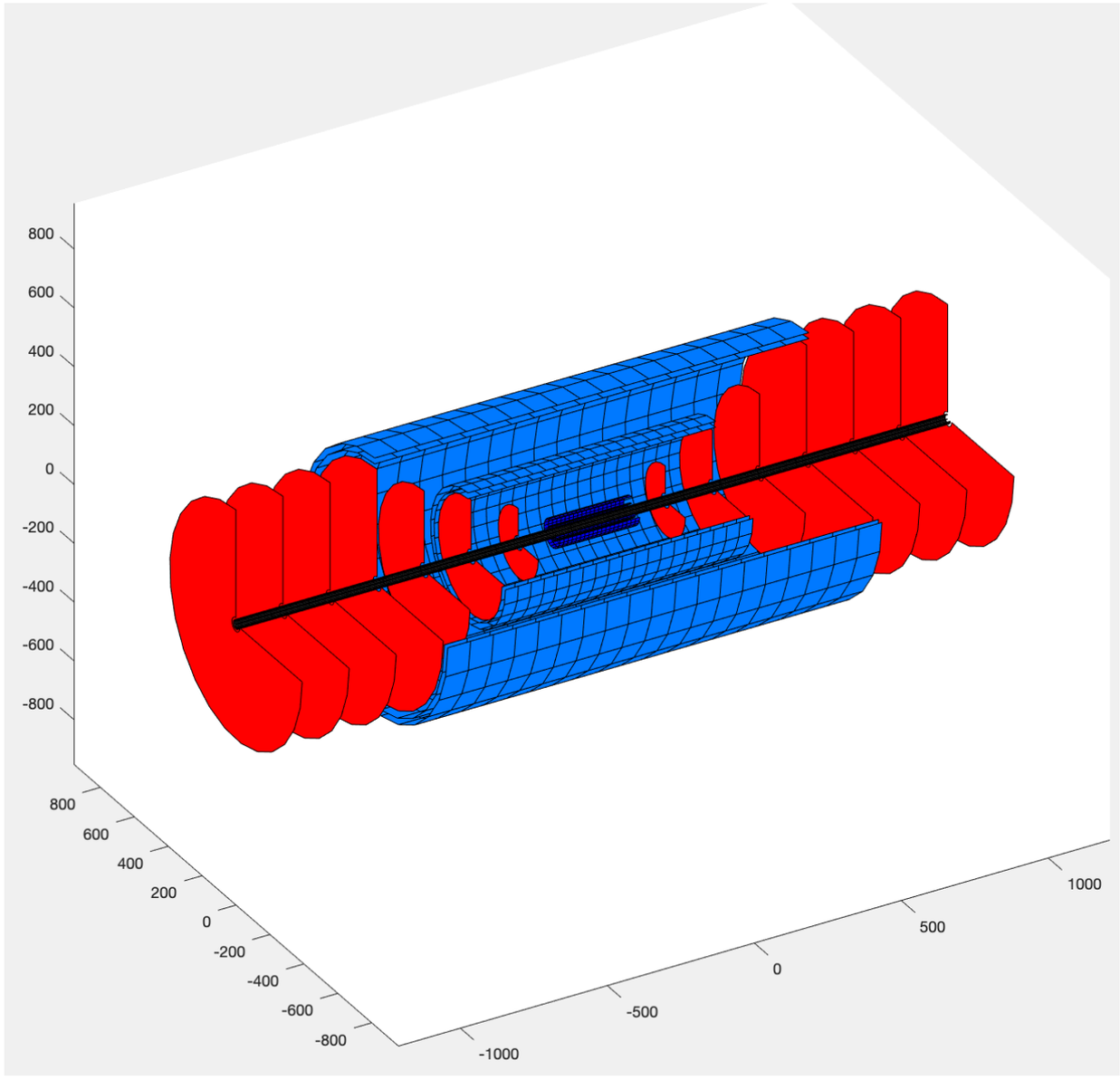


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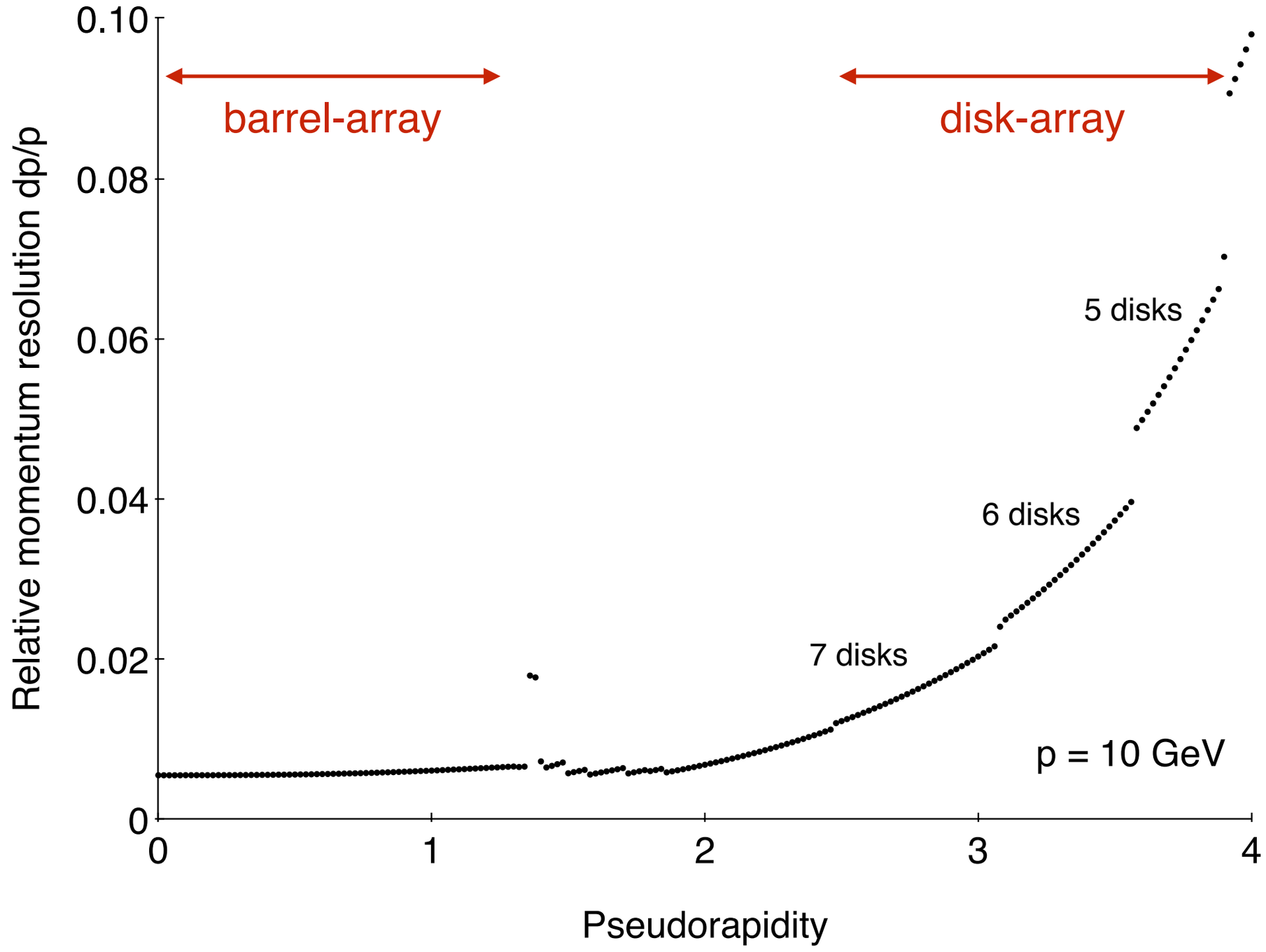

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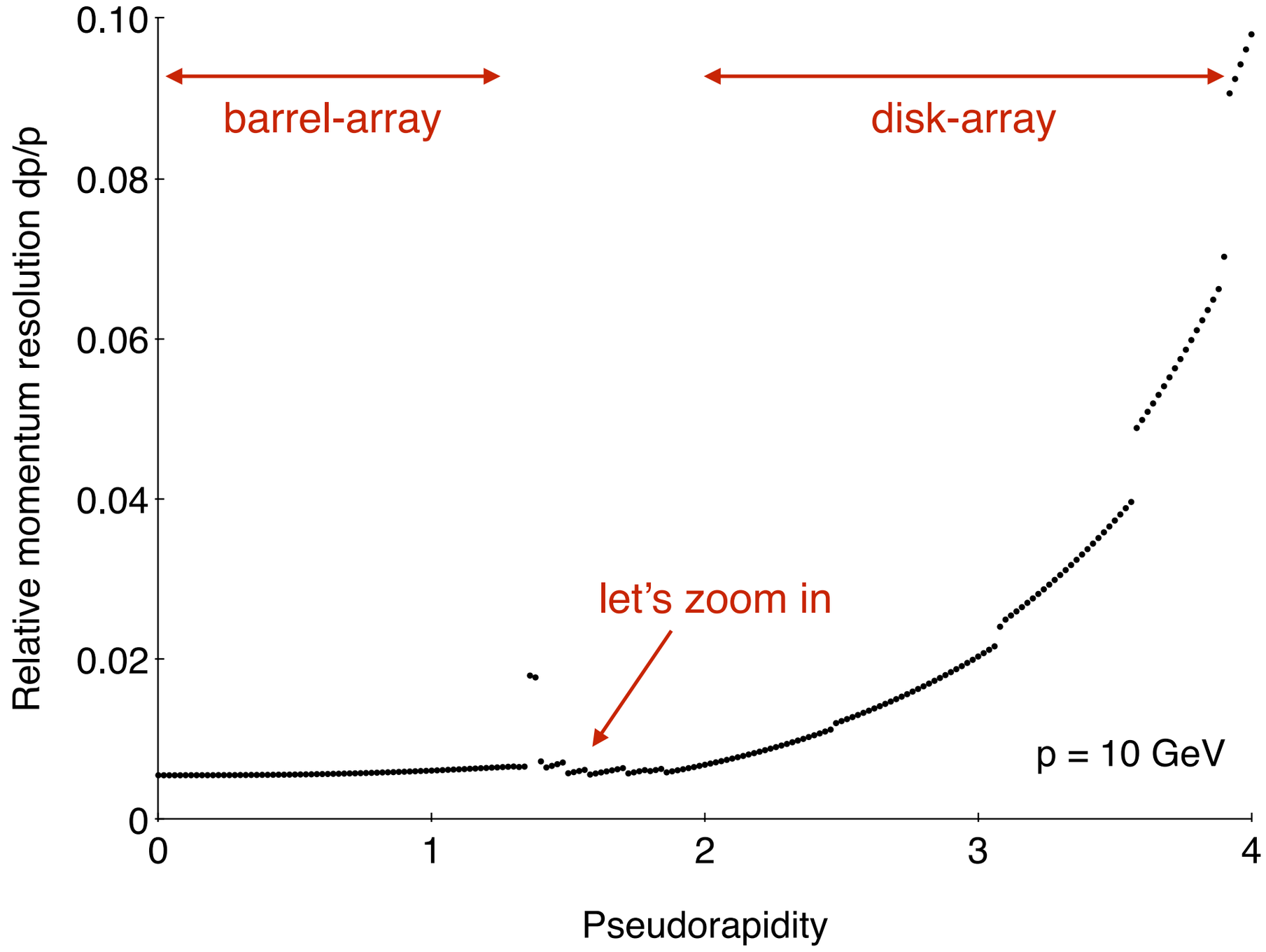

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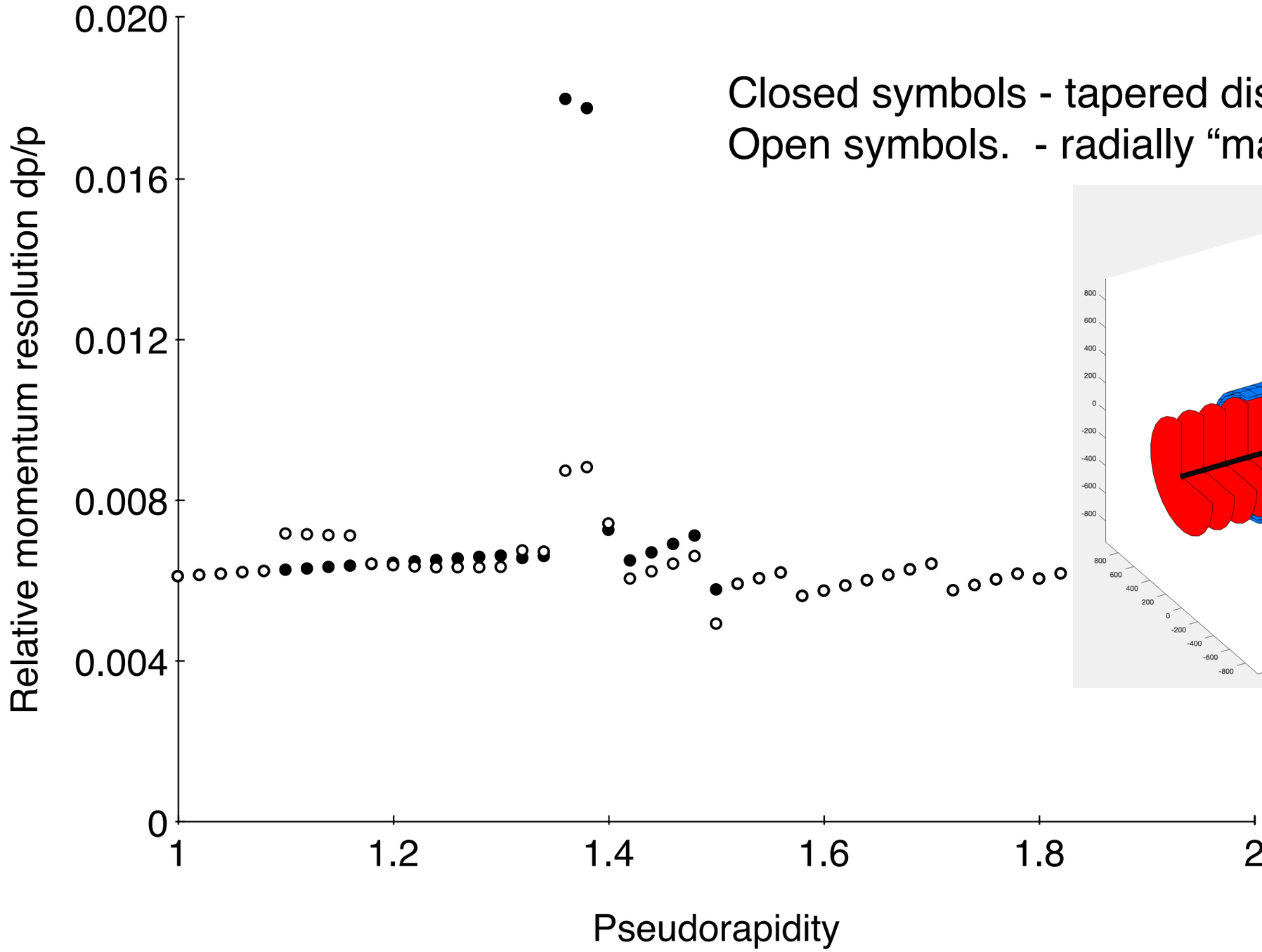
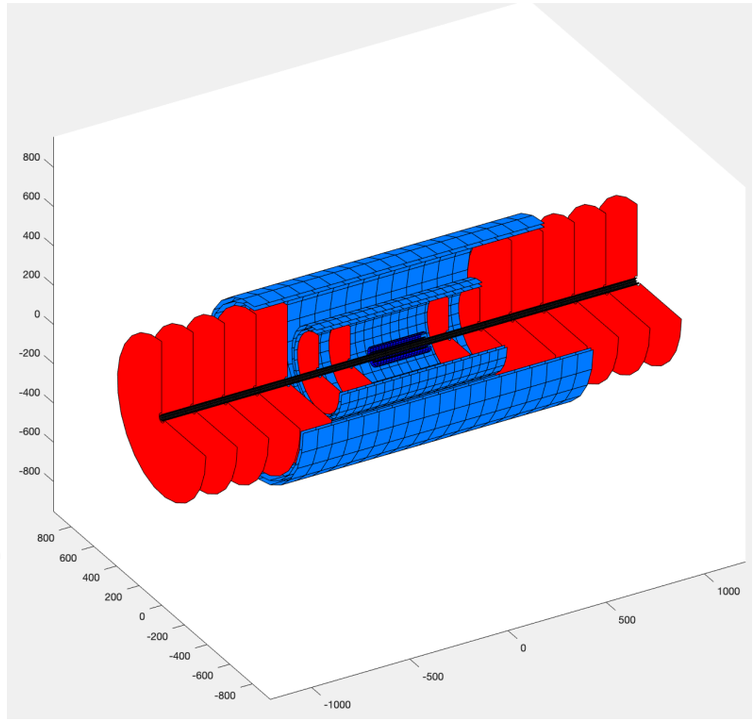
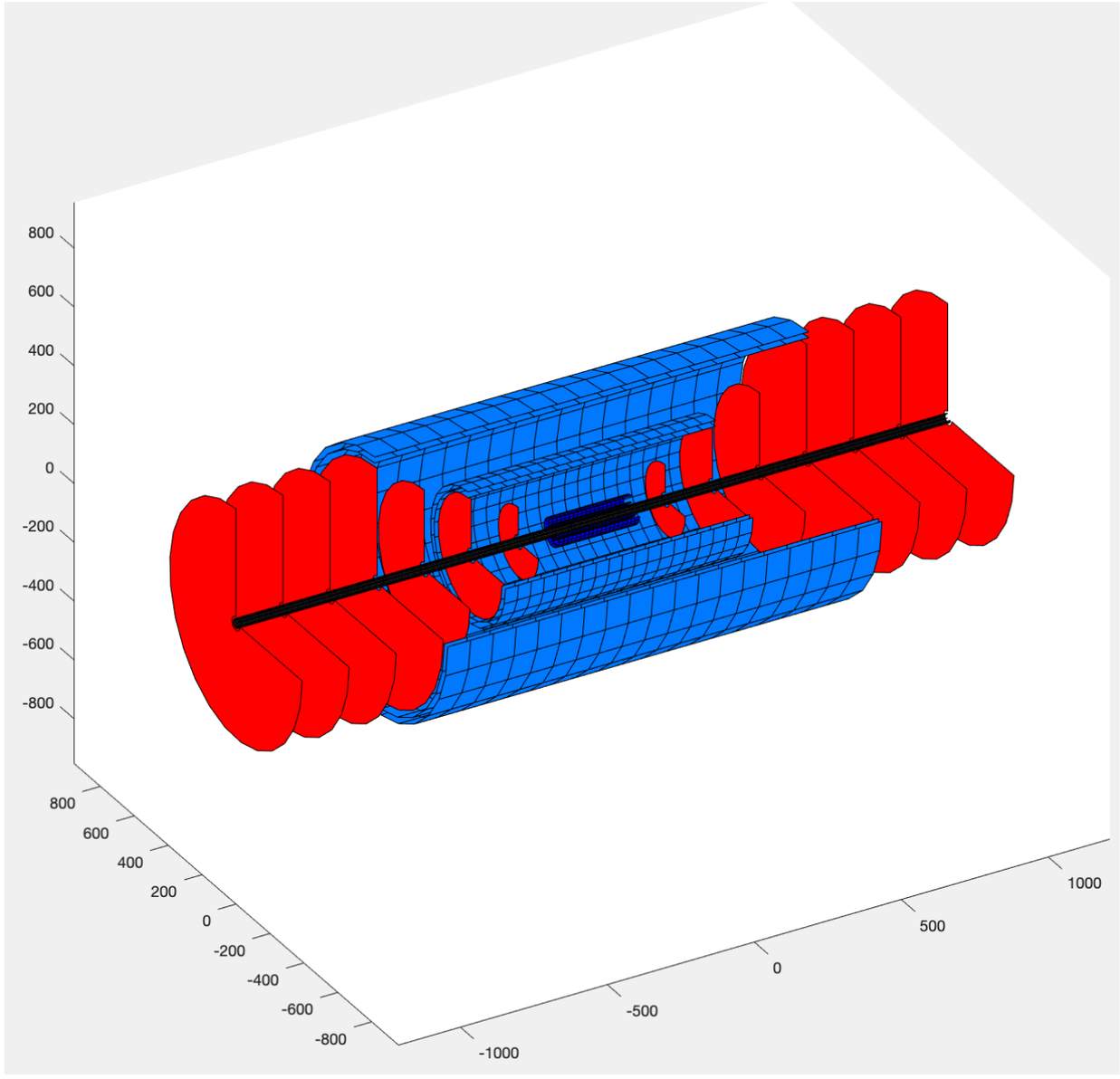



- Closed symbols - tapered disks (c.f. p15,16)
  Open symbols. - radially “maxed-out” disks:



- Tapering has mostly a small effect on dp/p; may offer flexibility for support and services in a trade-off with disk-complexity.

# eRD16 - EIC R&D Simulations

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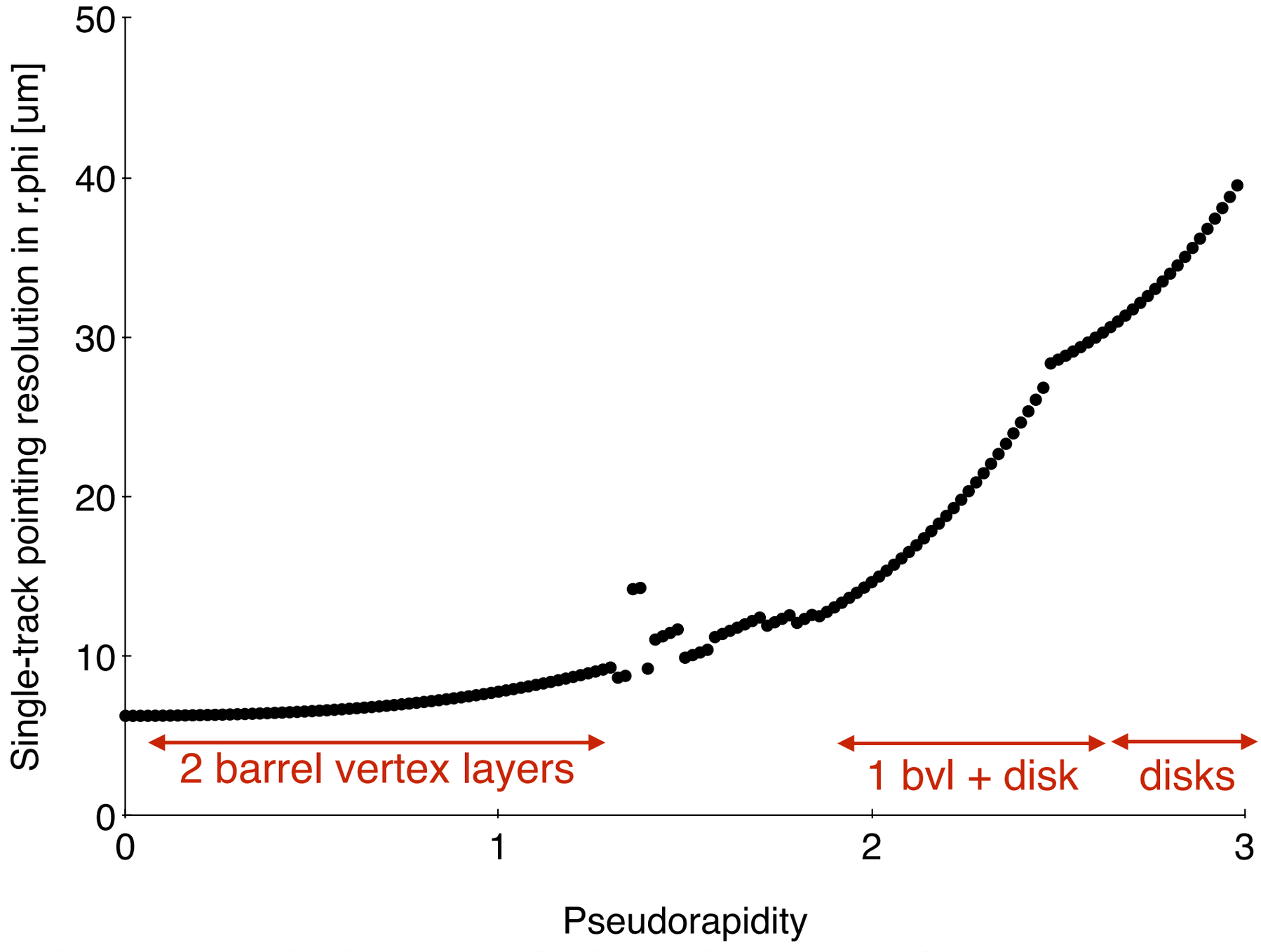


- r.phi and z pointing-resolution differ mostly by the dip-angle.

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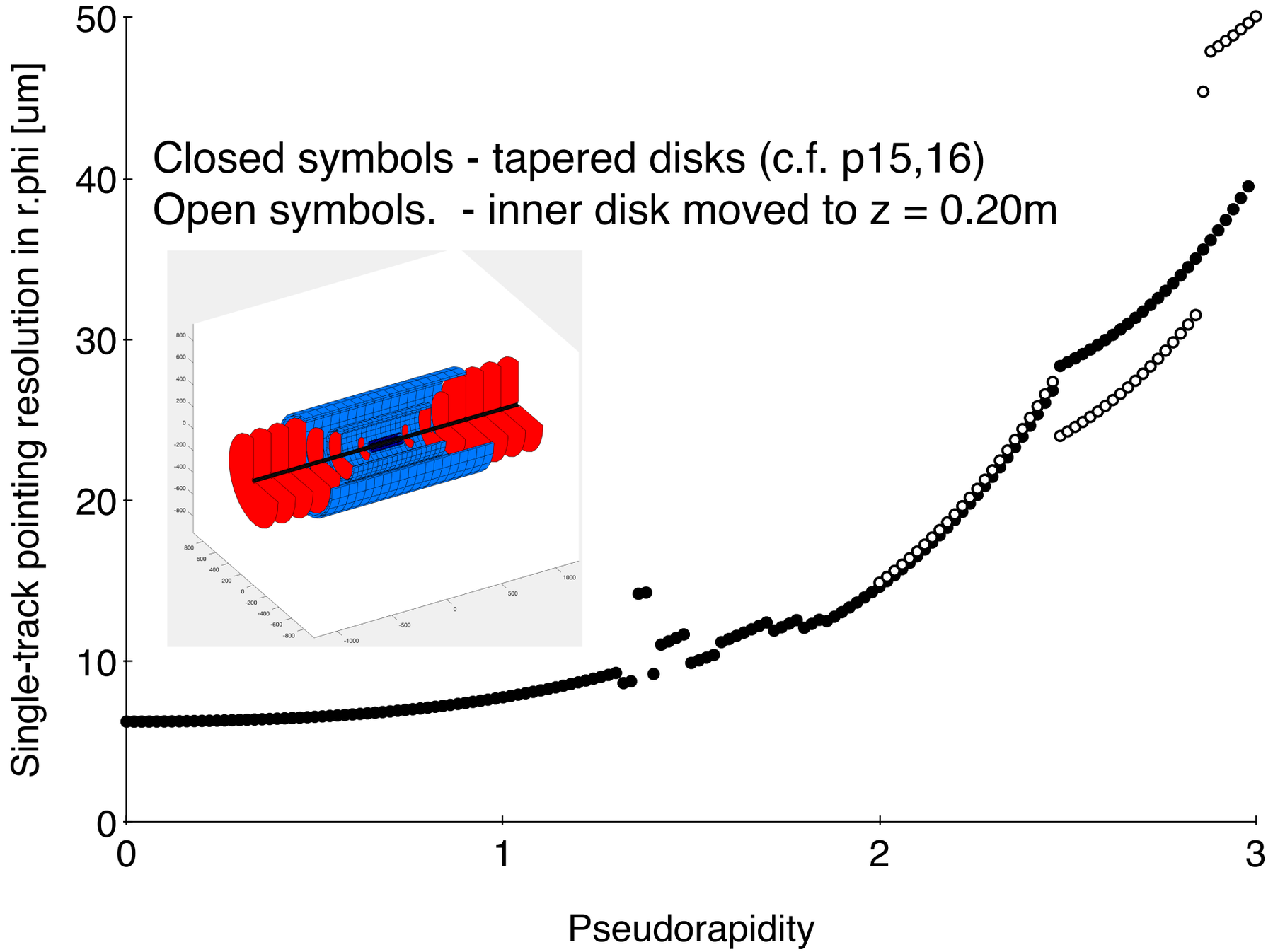


- collision vertex spread will of course spread these out.

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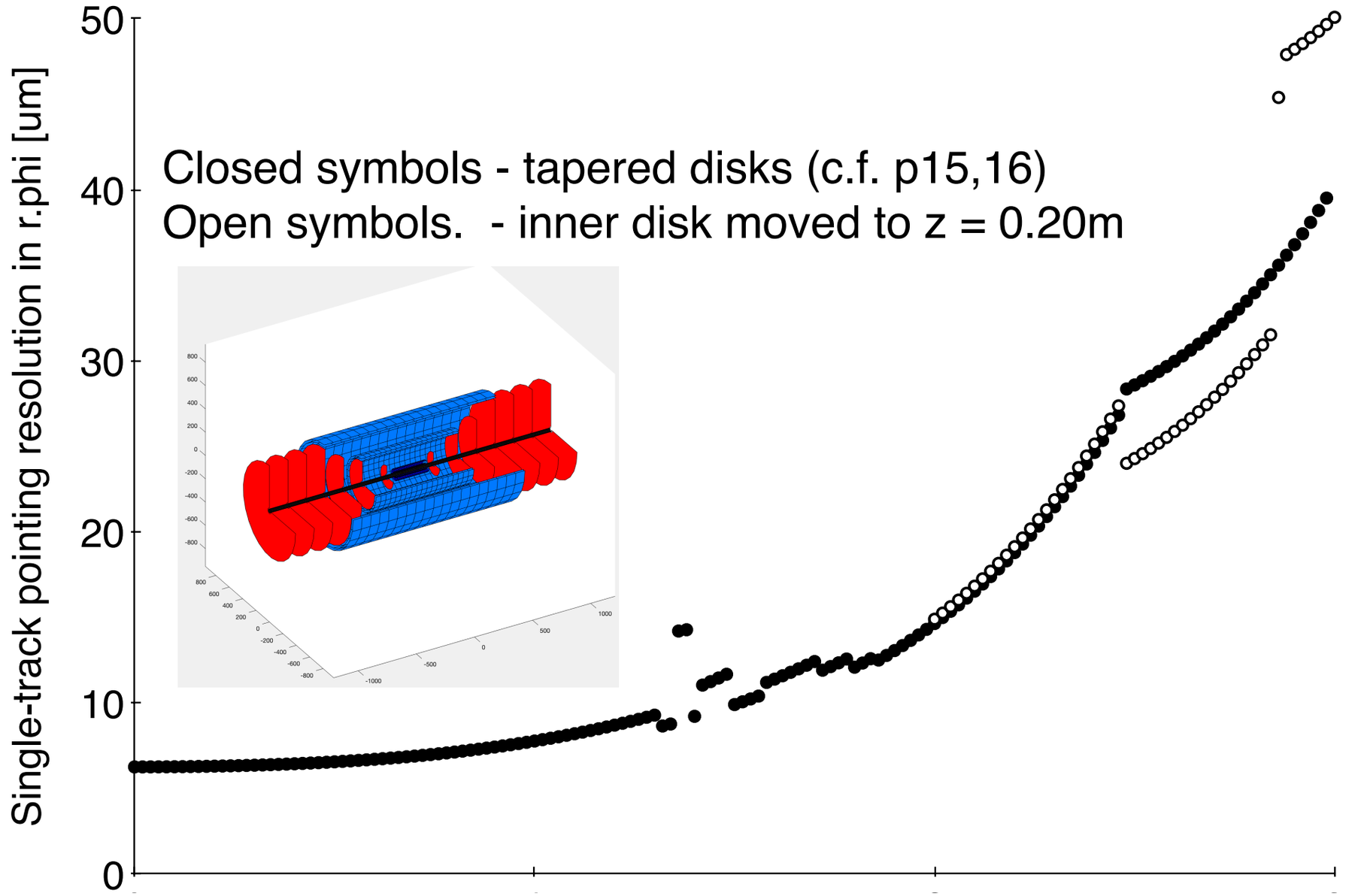



- Response-studies will need to be paired with science studies to further settle the configuration; further integration of event-generator(s) and LDT ongoing (w. SBU undergraduate Emily Biermann).

# eRD16 - Closing Comments

*Simulations have given insight in geometrical layout and sensor specifications for Si-based inner forward/backward trackers,*

*Fast simulations close to complete, documentation remains to be finished,*

*Slow simulations are now on track and are catching up with fast-simulations,*

*Overall reasonable agreement between fast and slow simulation results; several further studies ongoing*

*Gained initial insights into the interfacing of central and forward trackers,*

- *pursue long innermost barrel vertex layers,*
- *radial tapering of disks has minimal impact on dp/p performance; offers flexibility for mechanical support, interfaces,*
- *other key factors are coming in better focus,*

*Initial set of fast simulations towards an all-Si tracker are starting to come together,*

*eRD16 and eRD18 continue collaboration,*

*FY17 and FY18 LDRD has ended / will not continue into FY19,*

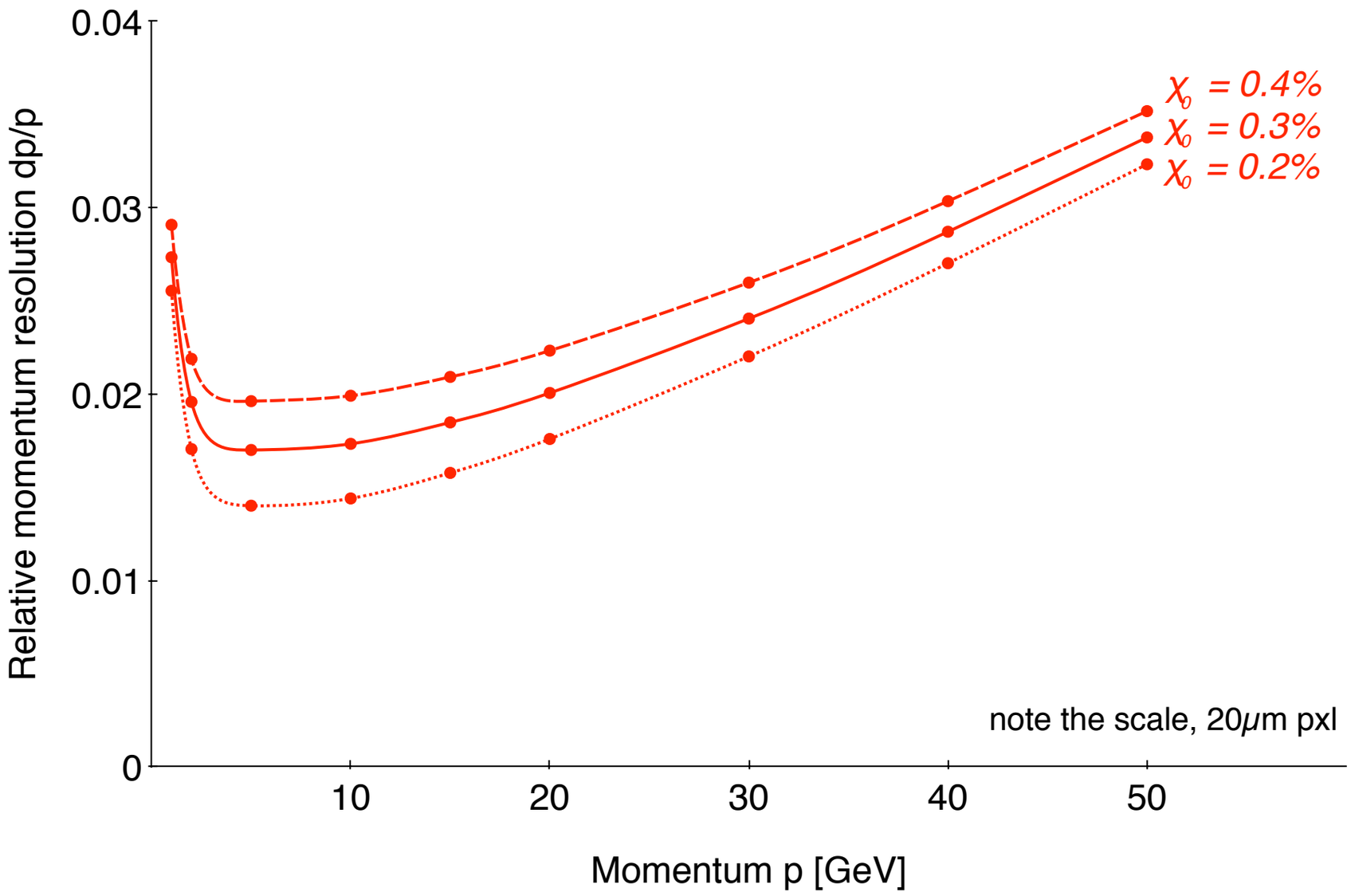
*Proposal to 2019 U.C. Multi-campus Research Funding Opportunity awarded,*

*Thank you!*

# Backup

# eRD16 - EIC R&D Simulations

LDT scan of pixel-size; 7 equidistant disks in a 3T field (BeAST):




Pseudo-rapidity is 3 here; measurements from all disks.

Momentum is *inside* the beam-pipe here; upturn at low (absolute) momentum originates mostly with uncertainty in the dip-angle.

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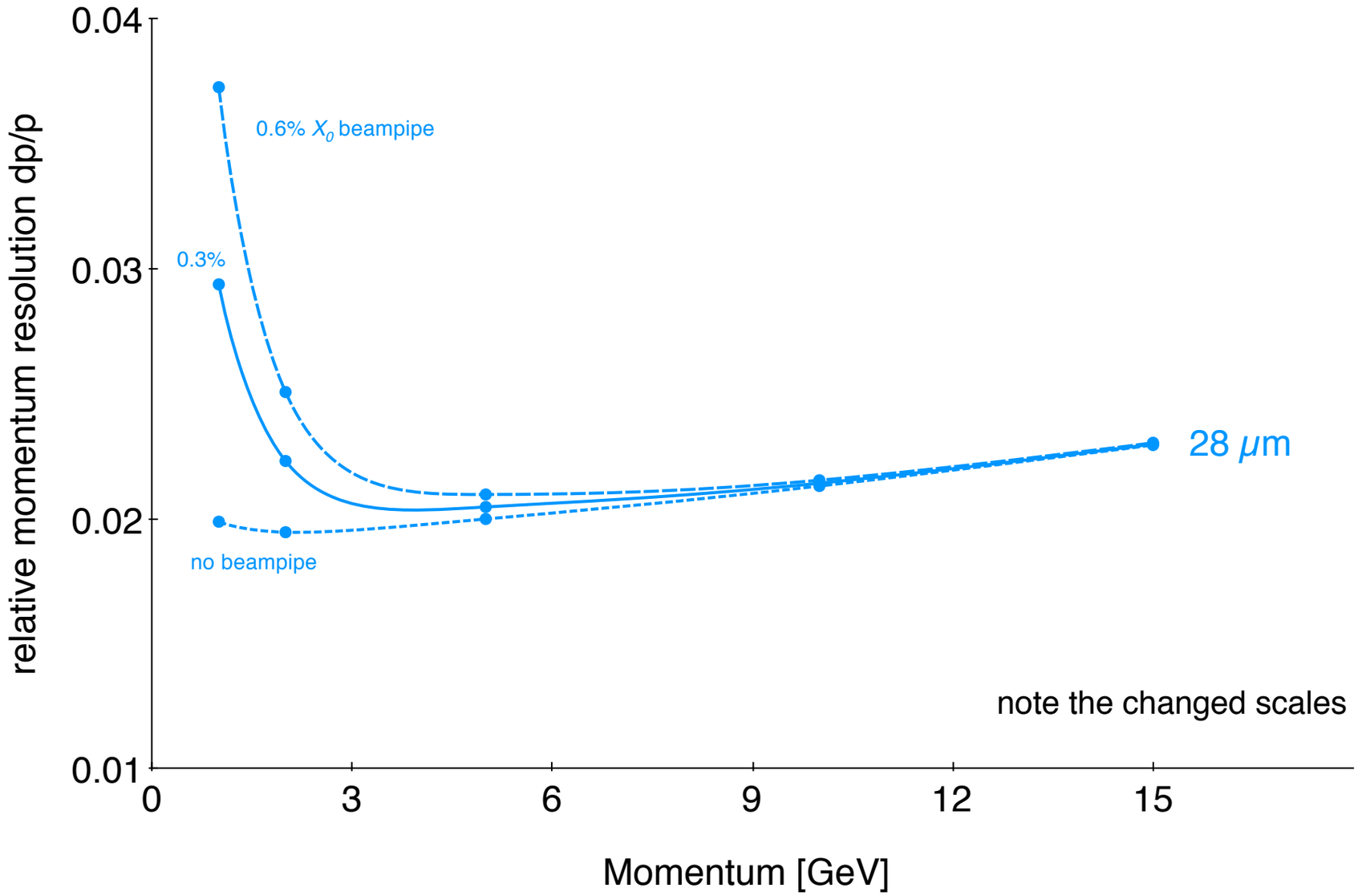


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